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Book

Local Area and Multiple Access Networks (ed), Computer Science Press, Rockville, MD 1986.

Patents Granted:

- 2,946,845 - Gain Control of Demodulators
- 3,180,205 - Distance-measuring Apparatus
- 3,180,927 - Cryptosecure Transmission System
- 3,453,870 - Self-contained Mass Measurement
- 3,675,131 - Coherent Phase Locking in Data Modems

Consulting and Contract Work:

- IBM Research (1968-71)
- Fairchild Industries (1971)
- U.S. Department of Commerce (1978)
- Computer Sciences Corporation (1964-68)
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- Communications Systems Inc.
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- Institute for Defense Analysis (1974-present)
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- AFC Corporation (1981-83)
- Warner Amex Communications (1982-84)
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- Vega Precision (1984-88)
- Broadcom (1985-87)
- Davis Roxie Faithful and Mapgood (1988)
- ECCO (1989)
- Pactel Cellular Communications (1989)
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Professional Courses Taught:

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MITRE Corporation
Planning Research Corporation
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Invited Lectures

"Digital Satellite Communications," Manitoba Section of IEEE, Jan. 1977.

"Time Division Multiple Access," British Columbia Communications Society, Feb. 1977.

"Orthogonal Signals, Hadamard Transforms, and Green Machines," McGill University and Universite' du Quebec, April 1977.

"A New Adaptive Routing Algorithm for Packet Switched Data Networks," University of Maryland, 1977.

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"Current Developments in Computer - Controlled Electronic switching," IEEE Washington Section Communications Society, Feb. 1978.

"Time-Division Digital switching," Computer Science Colloquium, University of North Carolina, April 1978.

"Spread Spectrum Communications - Fresh Insights", Computer Science/Electrical Engineering Colloquium, North Carolina State University, October, 1979.

"Data Communications," University of Ottawa Symposium, 1980.

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"Transient Behavior of Adaptive Null Steering Antenna Arrays," Institute for Defense Analyses, 1980.

"Analysis of Pseudo-Noise Spread Spectrum Communications Via A Hard Limiter," Electrical Engineering Dept. Colloquium, University of Virginia, 1981 and at INTELSAT Corp. Seminar, 1981.

"Current Topics in Communications Theory," Cairo, Egypt, 1981.

"Design and Analysis of Data Communications Systems," Electrical Engineering and Computer Science Department Joint Seminar, North Carolina State University, 1981.

"New Developments in Data Communications," University of Mexico, Mexico City, 1982.

"Cryptographic Methods of Data Protection," Washington Philosophical Society, Washington, D.C. , 1982.

"Issues in Underwater Acoustic Communications," Acoustic Speech and Signal Processing Workshop, Washington, D.C., 1982.

"Coding for Multi-User Communications," Department of Electrical Engineering, San Diego State University, 1983.

"Spread Spectrum and Multiple-Access Communications," 4 lectures in the Distinguished Lecture Series, Department of Computer Science

"Adaptive Arrays", George Mason University and IEEE.

"Local Area Networks with Priority Channels", Computer Sciences Corporation, Falls Church, VA, Feb., 1985.

"Local Area Networks", NASA, Goddard SPC, Greenbelt, MD, Feb., 1985.

"Coding for Multi-User Communications and Applications to Local Area Networks", University of Waterloo, Feb., 1985.

"Protocols for Network Security", IEEE National Capital Area
Symposium, February, 1987.

"Adaptive Arrays: Algorithms and Analysis" IEEE Baltimore Section

"Data Communication For A Paperless Society", New Jersey Institute of Technology, January 1989.

"Data Protection and Security in Networks" ICCC, Tel Aviv, ISRAEL, October 1988.

"Lower Bounds on Angle of Arrival Estimation with Arrays" Melpar Research Seminar, September 15, 1989.

"Fast Packet Switching" Panelist and Moderator at Multimedia Symposium at Montebello, P.Q. Canada, 1989.

"ATM Switch Technology" MCI Technology Symposium, October 1989.

"Lower Bounds on Angle of Arrival Estimation with Arrays", Melpar Research Seminar, Falls Church, VA , September 1989.

"Code Division Multiple Access", Society of Old Crows, Santa Barbara, California, July 1990.

"TDMA v.s. CDMA for Personal Communication Networks" Contel Technology Seminar, Reston, VA, October 1990, Hughes Network Systems, Germantown, MD , November 1990, COMSAT Laboratories, Clarksburg, MD, November 1990.

"WIDE: A Broadband Direction Estimator", The Moore School of Electrical Engineering, University of Pennsylvania, Phila, PA, Jan. 1991.

"Mobile Communications" California Institute of Technology, Pasadena, CA, Feb. 1991.

"Issues and Techniques of Microcellular Personal Communications Networks" International Symposium, Mexico City, Mexico, October 1991.

"New Methods for Digital Signature Authentication" MRJ, Inc. Reston, VA, October 1991.

"Spatial Selectivity Using Arrays for Low Probability of Interference in Mobile Communications", Z-Systems, Falls Church, VA, November 1991.

"Communications, Trends and Directions" (keynote) COMMSPHERE '91, International Conference, Herzlia, Israel, December 1991

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"personal Communications", panelist INFOCOM '92, Florence, Italy, April 1992.

"Wireless Networks" (keynote speaker) 15th Biennial Symposium on Communications, Queens University, Kingston, Ontario, CANADA, May 1992.

"TDMA In a Dispersive Channel" Department of EE and CS, Concordia University, Montreal, Quebec, CANADA, May 1992.

"Personal Communications", panelist, National Telesystems Conference, The George Washington University, Virginia Campus, May 1992.

"Microcellular Networks", MITRE Corp. Reston, VA, August 1992.

"personal Communication Systems", LCC Cellular Institute, Arlington, VA, September 1992.

"CDMA for Cellular Networks", Clemson University, Clemson, S.C., October 1992.

"Mobile Communications", Panel Chair, MILCOM '92, San Diego, CA, 1992, October 1992.

"New Results in the Comparison of TDMA and CDMA for Microcellular Systems", George Mason University, November 1992.

Course and Curriculum Development:

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Polytechnic Institute of Brooklyn (now Polytechnic University)
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Communications Laboratory I
Communications Laboratory II
Linear Systems, I, II, III
Digital Signal Processing
Stochastic Processes I, II
Electronic Laboratories

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The George Washington University

- EE 204 - Stochastic Signals and Noise
- EE 205 - Stochastic Processes in Electrical Engineering
- EE 208 - Digital Image Processing
- EE 241 - Information Theory
- EE 242 - Coding Theory
- EE 243 - Communication Theory I
- EE 244 - Communication Theory II
- EE 245 - Signal Detection and Estimation Theory
- EE 246 - Digital Communication
- EE 248 - Computer Communication Networks I
- EE 249 - Computer Communication Networks II
- EE 250 - Data Communication Security
- EE 252 - Digital Signal Processing Techniques
- EE 257 - Secure Communications: Spread Spectrum and Cryptography
- EE 258 - Radio Communications Systems I
- EE 259 - Radio Communications Systems II
- EE 277 - Satellite Communications Systems
- EE 245 - Advanced Detection Theory
- EE 346 - Communications Switching and Traffic Theory
- EE 450 - Telecommunication Systems Concepts
- EE 451 - Survey of Telecommunications Systems
- CS 244 - Data Communications
- CS 213 - Discrete Structures in Computing

Directed:

Masters Thesis Supervised
35 Theses (approximate)

Ph.D. Dissertations Supervised
26 Dissertations

**Theoretical and Field Performance
of Radiolocation Systems**

June 25, 1993

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Table of Contents

Abstract	1
1 Introduction	1
2 The PacTel Teletrac LMS System	2
3 Impact of wide-band interference on the location accuracy of a TDOA system	3
3.1 Model Analysis of Teletrac System	3
3.2 Analysis of a System	7
4 Experimental Validation of the Teletrac Model	10
4.1 Effect of Forward-link Interference on Receive Site Availability	10
4.2 Effect of Forward and Reverse Link Interference on Location Accuracy	13
4.2.1 Description of Experiment	13
4.2.2 Effect of Interference from a Forward-link Transmitter	14
5 Performance of the Teletrac Receiver	16
6 Conclusions	17

Abstract

This report presents an analytical model for assessing the detailed performance in a specific geographic area of a Location and Monitoring System in the presence of noise and interference. The report also presents the results of measurements on Teletrac's operating system in Dallas-Fort Worth that confirm the predictions of the analytic model and that show that an LMS system would generate fatal interference into a collocated, co-channel LMS system. We then apply the model to a system with parameters similar to those of Pinpoint's LMS system. The model predicts that the coverage of a Pinpoint-like system will be significantly reduced in the presence of co-channel interference from a similar system.

1 Introduction

Location and Monitoring Service (LMS) systems that employ wideband pulse ranging use two radio communications links — a forward link to relay information and locations requests to Radio Location Units (RLUs) located in the vehicles being monitored, and a return link which carries the location signal and status information from the vehicle to the fixed network.

If two LMS systems were to share the same channel in the same area, the prospect would arise of interference between the systems. Since location accuracy is an essential part of any location system, we examine the impact of such interference on location accuracy.

PacTel Teletrac developed an analytic model, based upon radio propagation modeling and the fundamental performance limits of hyperbolic navigation systems, that predicts system performance under a variety of system configuration and interference scenarios. Teletrac developed this model as a tool to use in the design and management of its existing and planned LMS systems. Teletrac engineers have used this model successfully to design and analyze Teletrac's existing systems in Los Angeles, Chicago, Dallas-Fort Worth, Detroit, Houston, and Miami.¹

To verify the model, an experiment was conducted in Dallas-Fort Worth which showed reasonable agreement with the model's predictions for operation in the presence of noise and interference.

¹ The model runs discussed in this report were calculated with the multipath analysis option in the Teletrac model turned off. Production use of the model has included use of the multipath option. Since consideration of multipath effects would degrade system performance, our calculations remain a bound on system performance.

We used the model to predict the performance of a system similar to the system proposed by Pinpoint². This analysis, which is discussed in more detail below, shows that performance of a Pinpoint-like system will be significantly impaired by interference from a co-channel LMS system.

Section 2 briefly describes the Teletrac LMS system. Section 3 describes the Teletrac model of a hyperbolic location system and also shows the model's prediction of the impact of wide-band interference on both a Teletrac-like and Pinpoint-like system.

Section 4 presents the experimental measurements made on the Teletrac system in Dallas-Fort Worth and compares those measurements to the model predictions. Section 5 describes measurements of the performance of Teletrac's receivers. We offer our conclusions in Section 6.

2 The PacTel Teletrac LMS System

The Teletrac LMS system is made of two major components -- a fixed network and radio location units (RLUs). The fixed network consists of several forward link transmitters, multiple receive sites throughout the coverage area, and a single central control center. The RLUs are transponders that respond to forward link by transmitting a pulse consisting of repetitions of a 1023-chip PN sequence modulated on a 908 MHz carrier. The RLU transmits at 5 watts and normally operates with a -6 dB antenna gain (typical of hidden installations for anti-theft applications). The Teletrac system also uses a -12 dB gain antenna for some applications.

The base stations accurately measure the time of arrival of the pulses from the RLUs. The Teletrac location system then uses a time difference of arrival (TDOA) technique to locate the RLU. The times-of-arrival are sent from base station to the control center which then solves for the location of the vehicle. The Teletrac system, like any ranging-based location system, is sensitive to the effects of noise, multipath and geometric dilution of precision (GDOP) all of which cause differences between the estimated location calculated by the system and the actual location of the vehicle.

² We considered an LMS system, like that proposed by Pinpoint, that used the same channel to carry wideband transmissions for both the forward and return links. In particular, we modeled the interference generated by the forward link transmissions of such an LMS system to the return channel transmissions of another co-channel, colocated LMS system.

3 Impact of wide-band interference on the location accuracy of a TDOA system

We assume that interference is the only source of error in the time-of-arrival measurements. Thus, real world performance will be worse than our model indicates. We further assume that interference can be modeled as additive gaussian white noise. This assumption is quite reasonable since we assume that both LMS systems will be using spread spectrum techniques³ that effectively treat uncorrelated signals as white noise. Treating interfering signals as white noise is reasonable for either wide-band or narrow-band interfering signals. The key assumption is that the interfering signal is ~~uncorrelated with the desired signal~~.

3.1 Model Analysis of Teletrac System

We used the model to predict the coverage area of the Teletrac system in Dallas-Fort Worth. We gave the model the actual parameters of Teletrac's Dallas-Fort Worth system as inputs. We reduced the sensitivity of base stations to account for the effects of existing inband noise as shown in Table 1.⁴

Site Name	Reduction in Sensitivity (db)
AR	0
EU	0
GR	2
AL	0
RE	2
AC	1
CA	1
PL	0
MN	0
OX	10
LW	1
CL	9
MY	0
BR	19
MK	0
MS	3
DN	5
LE	5

⁴ We note that Table 1 shows a favorable noise environment in Dallas-Fort Worth. Teletrac has observed substantially higher average noise in several cities. Increases of 10 to 20 dB over the noise floor are common in our experience.

BY	0
AA	2
SH	0
AZ	3
BP	11
KE	0

Table 1 Reduction of site sensitivities in Dallas-Fort Worth (measured 10 May 93)

Figure 1 shows the predicted coverage in normal operation. The regions in white have unacceptable location accuracy (DRMS beyond 1,000 feet) for LMS operations. Green represents areas with DRMS between 500 and 1000 feet and red shows locations with DRMS less than 500 feet.

Figure 2 shows the predicted coverage in the presence of a single interference source located on the eastern side of the service region. The interference is assumed to be a single wide band forward link transmitting at 32 watts mounted relatively high above the ground. Note that the model predicts that the coverage area would be substantially degraded in the presence of this interference.

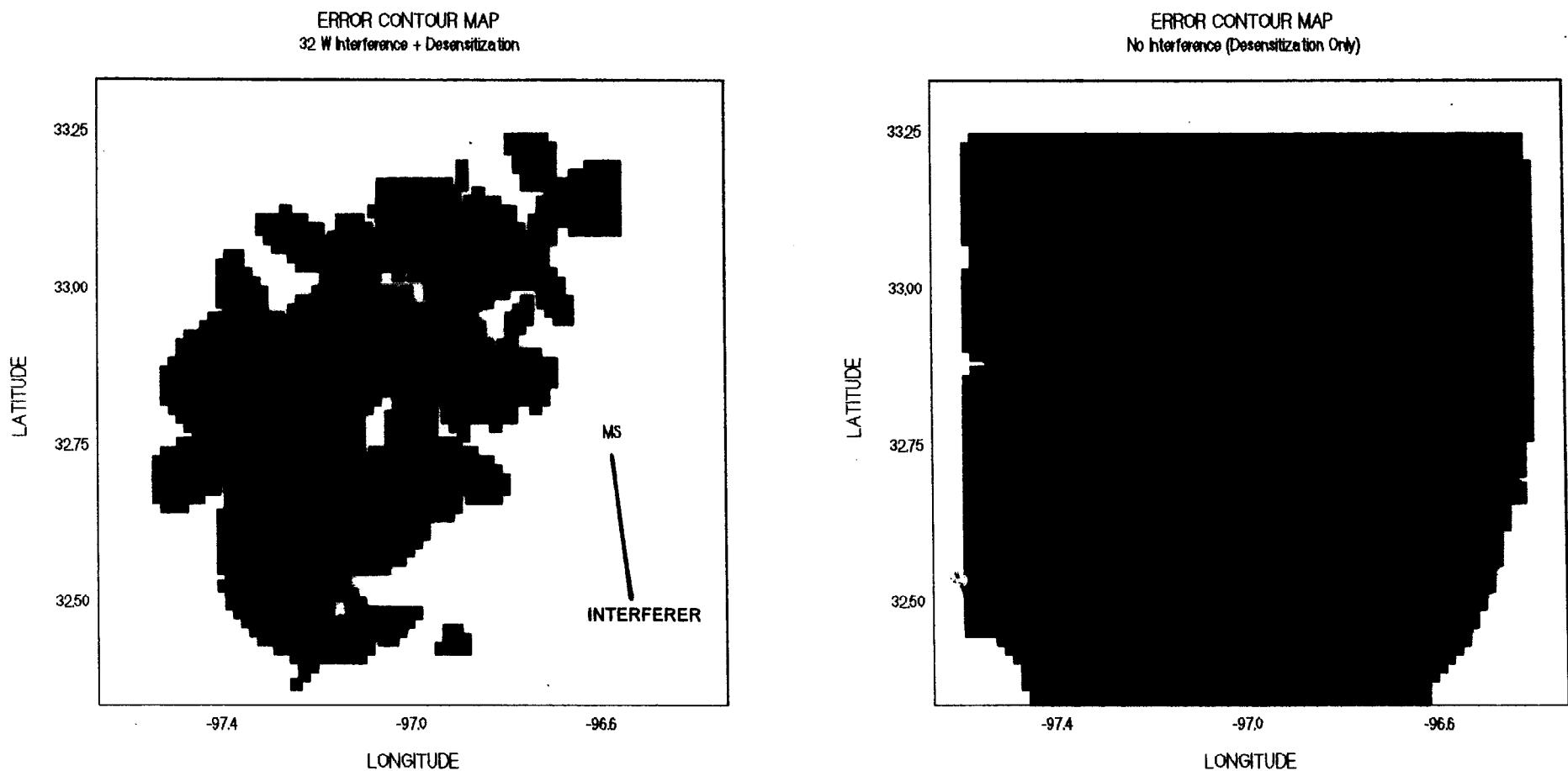


FIGURE 2 **Pactel Teletrac Coverage in Presence of Interference**

FIGURE 1 **Pactel Teletrac Coverage without Interference**

3.2 Analysis of a System Similar to the Proposed Pinpoint System

We considered a system with receive sites located at the sites proposed in Pinpoint's Dallas-Fort Worth application subject to interference from a similar system.[3] We assumed that the only source of error in our analysis is the interferer — that is we assume ideal receivers and no other sources of noise or system impairment.

We assume that interference arises from a base station with the characteristics of a proposed Pinpoint base station. In particular, power levels will be those proposed by Pinpoint for its base stations (484 watts), bandwidth will be 8 MHz and antennas will be well above ground. We model radio propagation between the interfering forward link transmitters and the subject receivers according to the free-space law. This is reasonable since both the transmit and receive antenna are located well above ground level.

ERROR CONTOUR MAP - Array
32 W Interference
Ideal Case(Without DESENSE . Perfect Synchronization . No Processing Gain Loss)

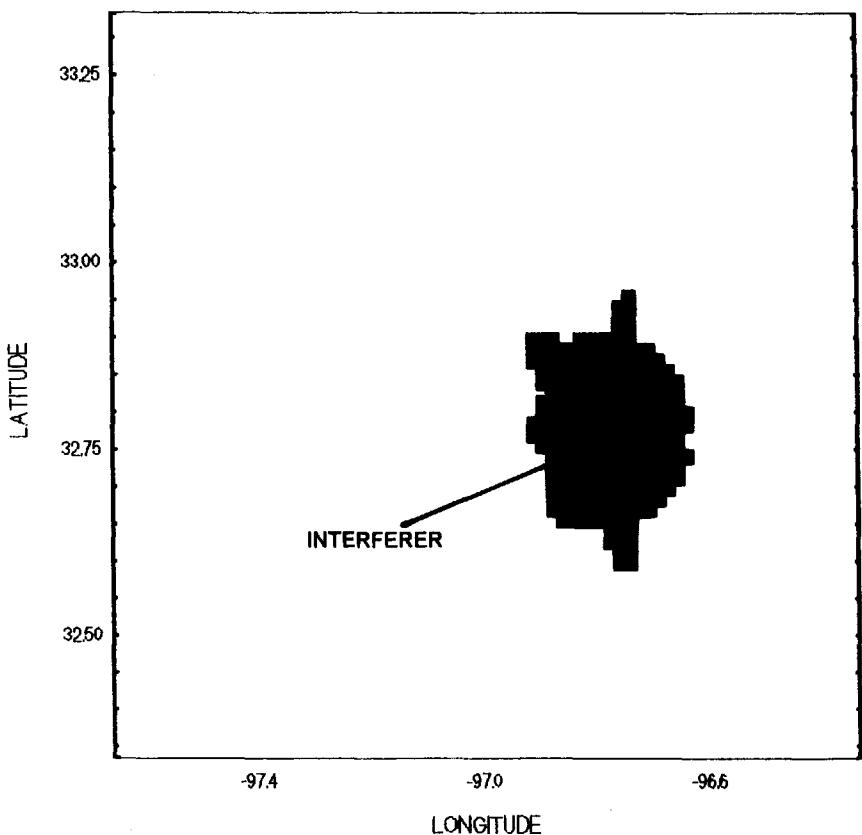


FIGURE 4 PinPoint Coverage in Presence of Interference

ERROR CONTOUR MAP - Array
No Interference
Ideal Case(Without DESENSE . Perfect Synchronization . No Processing Gain Loss)

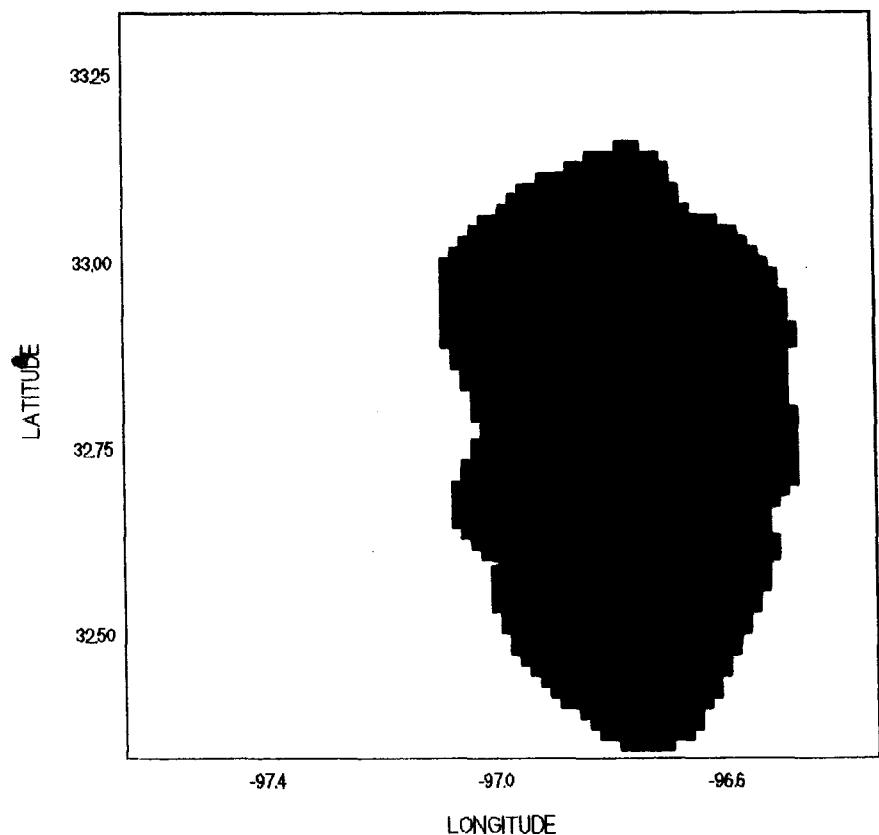


FIGURE 3 PinPoint Coverage without Interference